Valuation of Ecological Benefits: Improving the Science Behind Policy Decisions

PROCEEDINGS OF

SESSION I: SELECTED ECOLOGICAL VALUATION ACTIVITIES AT EPA

A WORKSHOP SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS (NCEE) AND NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH (NCER)

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Draft Ecological Benefits Assessment Strategic Plan





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October 2004

The following material describes the Draft Ecological Benefits Assessment Strategic Plan. The Plan has not undergone a final review and should not be construed to represent Agency Policy.

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  - David Charters
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  - Joel Corona
  - Doug Norton
- Contractor support, ICF
  - Margaret McVey

EPA and Ecological Benefits

- The mission of EPA is to protect human health and the environment.
- To that end, EPA
  - Develops and enforces regulations
  - Sponsors and develops voluntary programs and partnerships
  - Conducts and sponsors environmental research
- Identifying, quantifying, and monetizing ecological benefits can improve decision-making.
- Benefit-cost analysis required by executive order and statute.
- EPA is increasingly asked to provide concrete support for programmatic decisions

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Ecological Benefits

- Any improvements in human well-being that are derived from ecosystem services.
- Difficult to quantify and monetize.
- Current state of the practice values a limited set of ecological services affected by Agency actions.

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Goal of the Strategic Plan

"To improve the Agency's ability to identify, quantify, and value ecological benefits in order to improve decision-making and better communicate the results of Agency actions."

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Objectives of the Strategic Plan

- "Clearly describe some of the major technical and institutional issues that prevent the Agency from conducting accurate and comprehensive ecological benefits assessments on a routine basis."
- "Identify directions for future research, data collection, and development of analytical tools."

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Objectives of the Strategic Plan

- "Propose activities to foster increased collaboration and coordination among the Agency's ecologists, economists, and other analysts in conducting ecological benefits assessments."
- "Propose institutional mechanisms to facilitate adaptive implementation of this Strategic Plan, including periodic adjustments of the Plan to reflect progress in the state of knowledge."

The Plan will help Offices develop program-specific Action Plans to guide investment in the development of the methods, models, and data needed to conduct accurate and comprehensive ecological benefits assessments.

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Contents of the Plan

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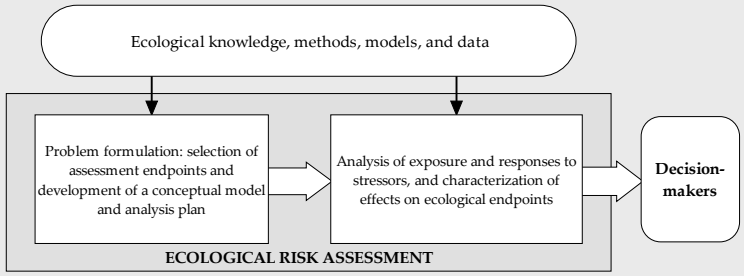
Section 4 – Improving Ecological Benefits Assessments

Contents Cont'd

Section 5 – Implementation

Ecological and Economic Assessments are Usually Separate



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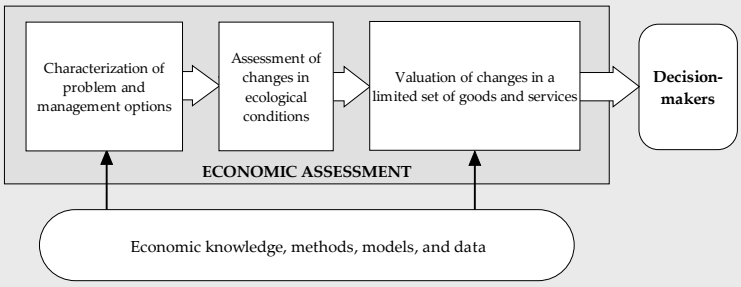
Ecological and Economic Assessments are Usually Separate



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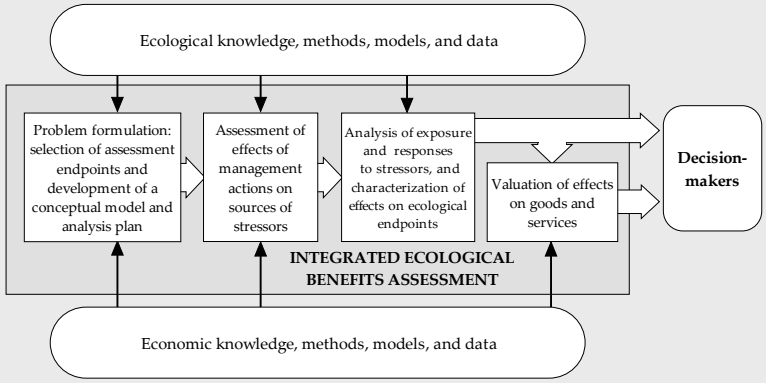
A More Integrated Process



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Section 4

- Describes some of the major ways in which EPA could improve its capabilities for conducting rigorous and comprehensive ecological benefits assessments on a routine basis.
- Describes key issues associated with ecological benefits assessments and actions that should lead to improvements.
- The actions address directions for future research, data collection, development of analytical tools, and institutional changes.

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Example Issues and Actions

Issue: Communication between ecologists and economists within EPA.

Action: Provide formal and informal opportunities for communication among disciplines.

Action: Provide basic training in the fundamentals of other disciplines.

Issue: Collaboration between ecologists and economists.

Action: Explore methods for expanding the use of ecological risk assessment information in economic benefits assessments.

Action: Require multi-disciplinary participation in assessing ecological benefits.

Action: Develop guidelines for planning and conducting ecological benefits assessments.

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Example Issues and Actions

Issue: Ability to predict changes in ecosystem processes in response to changing environmental stressors. Action: Identify which ecosystem processes are most important to benefits assessments at EPA.

Action: Identify which of the important ecosystem processes need further research to allow model development.

Action: Develop a catalogue of existing relevant ecosystem process models at different geographic scales to support benefits assessment.

Action: Expand portfolio of models to address the ecosystem processes important to benefits assessment at multiple geographic scales.

Action: Address data needs for those models.

Action: Evaluate other options for estimating changes in ecosystem processes.

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Example Issues and Actions

Issue: Using existing valuations studies for benefit transfer.

- Action: Encourage researchers to estimate values for a wider variety of ecological resources.
- Action: Encourage researchers to use standardized measures of ecological resources in valuation studies.
- Action: Encourage researchers to estimate and report values for a greater range of ecological changes.
- Action: Support the development of new publication outlets.

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Section 5

- Identifies Agency actions needed to implement the Plan.
  - *Further define research and development needs and communicate those needs by developing office-specific Action Plans.*
  - Develop a systematic method to guide prioritization of the investment opportunities identified in the Plan and individual program office Action Plans.
  - Track progress and integrating ecological benefits assessment into the Agency's base programs.

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Status

- SAB Committee on Valuing the Protection of Ecological Systems and Services review January 2005
- SAB Review Draft available late fall 2004
- Want a copy?
  - Sign-up sheet on registration table
  - Email owens.nicole@epa.gov

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Valuing Ecological Protection: A Tangle, a Web, or a Fabric?

A Look at the Work of the SAB Committee on Valuing the Protection of Ecological Systems and Services

EPA SAB Staff Office

History of Project

- SAB's Executive Committee conceived Project (2002)
- Project within SAB mission
  - To provide external, independent advice on the scientific and technical aspects of environmental issues to help inform environmental decision-making
  - Advice directed at the technical bases of EPA policies, regulations, research, and science programs
- Project supported as an SAB priority by EPA's Science Policy Council

EPA SAB Staff Office

Charge to the Committee

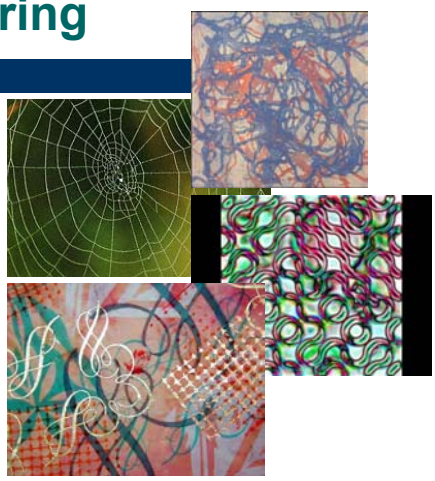
- To assess:
  - Agency needs and the state of the art and science of valuing protection of ecological systems and services
  - To identify key areas for improving knowledge, methodologies, practice, and research
- A multi-disciplinary, multi-year effort

Formation of Committee

- Committee formed in August 2003
- 24 members – with experience, expertise, and range of views in different fields
  - 7 Economists
  - 8 Environmental Scientists (Ecologists/Biologists)
  - 9 "Others":
    - Decision Science
    - Engineering
    - Law
    - Philosophy
    - Political Science
    - Psychology

Strategy and Steering

- "Value" – untangling its meanings
- Important to provide advice to help EPA make decisions
- Steering Committee established – February 2004



EPA SAB Staff Office

Focusing on 4 Types of EPA Needs

1. Valuation of ecological benefits for National Rulemaking
2. Assessing options, priority setting for Regional decision-making
3. Assessing ecological benefits for GPRA compliance
4. Communicating ecological benefits to the public

EPA SAB Staff Office

Key Technical Issues

- Addressing non-use values
- Expressing data quality and uncertainty
- Appropriate use of monetized, quantified, and qualitative methods
- Assumptions about:
  - Elasticity and substitution
  - Transferability
  - Stability of ecological systems
  - Discounting benefits
- Appropriate role of public in developing scientific information

EPA SAB Staff Office

Planned Committee Activities

- Advisory on Agency draft *Ecological Benefits Assessment Strategic Plan*
- Public meetings/workshops focused on EPA decision needs
- "Example Exercises" to meet those needs
- Public meetings on key technical issues
- Learning from/building on work of others
- Final report (2005-2006) addressing EPA's needs

EPA SAB Staff Office

US EPA Science Advisory Board (SAB) Committee on Valuing the Protection of Ecological Systems and Services
Fact-Sheet

Charge

The SAB initiated this project to assess Agency needs and the state of the art and science of valuing protection of ecological systems and services, and then to identify key areas for improving knowledge, methodologies, practice, and research.

Committee Membership

The Committee is an inter-disciplinary group (24 Members) of ecologists, economists, engineers, other environmental specialists, and related disciplines. A committee roster is attached to this fact sheet. The Committee has organized a Steering Group to assist the Chair and the Designated Federal Officer, Dr. Angela Nugent, in planning the work of the Committee.

Approach

To fulfill this charge, the SAB Committee appointed by the Administrator will conduct a multiyear initiative with the goal of providing a first approximation of the advice needed by the Environmental Protection Agency.

- They will also advise the Agency on its draft *Ecological Benefits Assessment Strategic Plan*
- They will host workshops on science-based approaches to valuing the protection of ecological systems and services used in practice by groups outside EPA: in other federal agencies, state governments, environmental groups, business entities and international organizations.
- The Committee will focus on specific EPA decision-making needs by reviewing a range of EPA analyses supporting those needs and by intensively working on related "examples."
- At the conclusion of the two-year initiative, the Committee will issue a final report assessing overall Agency needs and provide advice for strengthening the Agency's approaches for valuing the protection of ecological systems and services, their use by decision makers, and the key research areas needed to strengthen the science base.

Specific Areas of Focus on EPA Decision-Making Needs

- Needs for benefit assessments supporting regulations protecting ecological systems and services
- Regional needs for assessing and communicating the value of protecting ecological systems and services
- Needs for assessing and communicating to Congress, the Executive Branch, and the public the value of EPA's programs protecting ecological systems and services under the Government Performance and Results Act
- Needs for information/communication products to communicate to the general public about EPA regulatory decisions protecting ecological systems and services and information/communication products encouraging voluntary actions to protect ecological systems and services

Status of Work

- The Committee held an "Initial Background Workshop" on October 27, 2004. The purpose was to identify the range of EPA's needs for science-based information on valuing the protection of ecological systems and services.
    - Minutes are posted on the web at: http://www.epa.gov/science1/04minutes/cvpess_102703m.pdf.

- The Committee held a "Workshop on Different Approaches and Methods for Valuing the Protection of Ecological Systems and Services" on April 13-14, 2004.
    - Minutes are posted on the web at: http://www.epa.gov/science1/04minutes/valueprotecosys41304min.pdf

- The Committee held an Advisory Meeting focused on support documents for national rulemakings on June 14-15, 2004.
    - Minutes are posted on the web at: http://www.epa.gov/science1/04minutes/cvpess_061404m.pdf

- The Committee held an advisory meeting in San Francisco on Sept. 13, 14, and 15 focused on regional science needs, work-products, and activities by holding panel discussions, briefings, and break-out groups.
    - Minutes are posted on the web at: http://www.epa.gov/science1/04minutes/cvpess_091304m.pdf

    .
- The Committee will hold an advisory meeting on Jan. 25 and 26, 2005. The purpose of this meeting will be to review EPA's Draft Ecological Benefits Assessment Strategic Plan and Related Charge Questions and then to discuss science needs, work-products, and activities related to requirements under the Government Performance and Results Act for valuing the protection of ecological systems and Services.
    - Background materials for the meeting will be posted on the SAB web site (www.epa.gov/sab) as they become available.

For Additional Information

Please contact the Designated Federal Officer, Dr. Angela Nugent by email at nugent.angela@epa.gov or by phone at 202-343-9981.

U.S. Environmental Protection Agency
Science Advisory Board
Committee on Valuing the Protection of Ecological Systems and Services

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Valuing Ecosystem Services

Toward Better Environmental Decision-Making

National Research Council
Mark Gibson
Study Director

Presentation to U.S. EPA Workshop:
Improving the Valuation of Ecological Benefits
October 26, 2004

Available on-line at http:/www.nap.edu/catalog/11139.html

Committee and Process

- 5 meetings, 1 consensus report, extensive external review process
- Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems:
  - GEOFFREY M. HEAL, Chair, Columbia University
  - EDWARD B. BARBIER, University of Wyoming
  - KEVIN J. BOYLE, University of Maine
  - ALAN P. COVICH, University of Georgia
  - STEVEN P. GLOSS, U.S. Geological Survey
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Report Reviewers

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- Nancy Grimm, Arizona State University
- Michael Hanemann, University of California, Berkeley
- Peter Kareiva, The Nature Conservancy
- Raymond Knopp, Resources for the Future
- Sandra Postel, Global Water Policy Project
- Robert Stavins, Harvard University

Statement of Task

The committee will evaluate methods for assessing services and the associated economic values of aquatic and related terrestrial ecosystems. The committee's work will focus on identifying and assessing existing economic methods to quantitatively determine the intrinsic value of these ecosystems in support of improved environmental decision-making, including situations where ecosystem services can be only partially valued. The committee will also address several key questions, including:

Statement of Task (continued)

- What is the relationship between ecosystem services and the more widely studied ecosystem functions?
- For a broad array of ecosystem types, what services can be defined, how can they be measured, and is the knowledge of these services sufficient to support an assessment of their value to society?
- What lessons can be learned from a comparative review of past attempts to value ecosystem services—particularly, are there significant differences between eastern and western U.S. perspectives on these issues?
- What kinds of research or syntheses would most rapidly advance the ability of natural resource managers and decision-makers to recognize, measure, and value ecosystem services?
- Considering existing limitations, error, and bias in the understanding and measurement of ecosystem values, how can available information best be used to improve the quality of natural resource planning, management, and regulation?

Report Organization

EXECUTIVE SUMMARY

1. INTRODUCTION
2. THE MEANING OF VALUE AND USE OF ECONOMIC VALUATION IN THE ENVIRONMENTAL POLICY DECISION-MAKING PROCESS
3. AQUATIC AND RELATED TERRESTRIAL ECOSYSTEMS
4. METHODS OF NONMARKET VALUATION
5. TRANSLATING ECOSYSTEM FUNCTIONS TO THE VALUE OF
   - ECOSYSTEM SERVICES: CASE STUDIES
6. JUDGMENT, UNCERTAINTY, AND VALUATION
7. ECOSYSTEM VALUATION: SYNTHESIS AND FUTURE DIRECTIONS

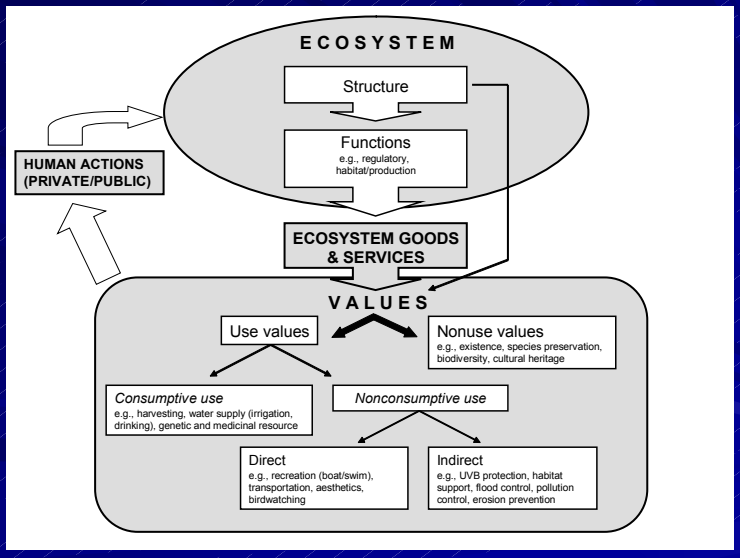
APPENDIXES

A Summary of Related NRC Reports
B Household Production Function Models
C Production Function Models
D Committee and Staff Biographical Information

Introduction and Overview

- The study was conceived in 1997 at a strategic planning session of Water Science and Technology Board of the NRC
- In early November 1999 the NRC organized and hosted a planning workshop to assess the feasibility of and need for an NRC study of the functions and associated economic values of aquatic and terrestrial ecosystems
- The report focuses on the goods and services provided by aquatic and related terrestrial ecosystems and reflects an intentional effort to focus on management and valuation issues confronting state and federal agencies for these ecosystems
- Because the principles and practices of valuing ecosystem goods and services are rarely sensitive to whether the underlying ecosystem is aquatic or terrestrial, the report's various conclusions and recommendations are likely to be directly or at least indirectly applicable to the valuation of the goods and services provided by any ecosystem

Connections Between Ecosystem Structure and Function, Goods and Services, Policies, and Values



The Meaning of Value and Use of Economic Valuation

- Recent philosophical debates regarding ecosystem value generally derive from two points of view (1) values of ecosystems and their services are non-anthropocentric and (2) all values are anthropocentric
- Although economic valuation does not capture all sources or types of value, it is much broader than usually presumed. It recognizes that economic value can stem from the use of an environmental resource (*use values*), or from its existence even in the absence of use (*nonuse value*)
- The broad array of values included under this approach is captured by using the total economic value (TEV) framework. The TEV framework helps to provide a checklist of potential impacts and effects that need to be considered in valuing ecosystem services
- A valuation question can be framed in terms of two alternative measures of value, willingness to pay (WTP) and willingness to accept (compensation) (WTA). These two approaches imply different presumptions about the distribution of property rights and can differ substantially
  - In many contexts, methodological limitations necessitate the use of WTP rather than WTA

The Meaning of Value and Use of Economic Valuation
Major Recommendations

- Policymakers should use economic valuation as a means of evaluating the trade-offs involved in environmental policy choices; an assessment of benefits and costs should be part of the information set available to policymakers in choosing among alternatives
- Economic valuation of changes in ecosystem services should be based on the comprehensive definition embodied in the TEV framework, including both use and nonuse values
- The valuation exercise should be framed properly. In particular, it should value the *changes* in ecosystem good or services attributable to a policy change

Aquatic and Related Terrestrial Ecosystems

- The phrase “aquatic and related terrestrial ecosystems” recognizes the impossibility of analyzing aquatic systems absent consideration of the linkages to adjacent terrestrial environments
- There have only been a few attempts to develop explicit maps of the linkage between aquatic ecosystem structure/function and value. There are, however, a multitude of efforts to separately identify ecosystem functions, goods, services, values, and/or other elements in the linkage
- From an ecological perspective, the value of specific ecosystem functions/services is entirely relative. The spatial and temporal scales of analysis are critical determinants of potential value
- There remains a need for a significant amount of research in the ongoing effort to codify the linkage between ecosystem structure and function and the provision of goods and services for subsequent valuation
- A comprehensive identification of all functions and derived services may never be achieved; nevertheless, comprehensive information is not generally necessary to inform management decisions

Aquatic and Related Terrestrial Ecosystems
Major Recommendations

- Aquatic ecosystems generally have some capacity to provide consumable resources, habitat for plants and animals, regulation of the environment, and support for nonconsumptive uses, but considerable work remains to be done in documentation of the potential of various aquatic ecosystems for contribution in each of these broad areas
- Because delivery of ecosystem goods and services occurs in both space and time, investigation of the spatial and temporal thresholds of significance for various ecosystem services is necessary to inform valuation efforts
- Natural systems are dynamic and frequently exhibit nonlinear behavior, and caution should be used in extrapolation of measurements in both space and time. Methods are needed to assess and articulate this uncertainty as part of system valuations

Methods of Nonmarket Valuation

- Although a variety of nonmarket valuation approaches are currently available, no single method can be considered best at all times and for all types of aquatic ecosystem applications
- Revealed-preference methods can be applied only to a limited number of ecosystem services. However, both the range and the number of services that can potentially be valued are increasing with the development of new methods
- Stated-preference methods can be more widely applied, and certain values can be estimated only through the application of such techniques
  - However, the credibility of estimated values for ecosystem services derived from stated-preference methods has often been criticized
- Benefit transfers and replacement cost and cost of treatment methods are increasingly being used in environmental valuation, although their application to aquatic ecosystem services is still limited and potentially problematic
- Only a limited number of ecosystem services have been valued to date, and effective treatment of aquatic ecosystem services in benefit-cost analyses requires that more services be valued

Methods of Nonmarket Valuation
Major Recommendations

- Specific attention should be given to funding research at the "cutting edge" of the valuation field, such as dynamic production function approaches, general equilibrium modeling of integrated ecological-economic systems, conjoint analysis, and combined stated-preference and revealed-preference methods
- Specific attention should be given to funding research on improved valuation study designs and validity tests for stated-preference methods applied to determine the nonuse values associated with aquatic and related terrestrial ecosystem services
- Benefit transfers should be considered a "second-best" method of ecosystem services valuation and should be used with caution and only if appropriate guidelines are followed
- The replacement cost method and estimates of the cost of treatment are not valid approaches to determining benefits and should not be employed to value aquatic ecosystem services. In the absence of any information on benefits, and under strict guidelines, treatment costs could help determine cost-effective policy action

Case Studies and Lessons Learned

- Chapter 5 provides a series of case studies of the integration of ecology and economics necessary for valuing the services of aquatic and related terrestrial ecosystems
  - First reviewed are situations in which the focus is on valuing a single ecosystem service. Even when the goal of a valuation exercise is focused on a single ecosystem service, a workable understanding of the functioning of large parts or possibly the entire ecosystem may be required
  - Attempts to value multiple ecosystem services are reviewed next. Since ecosystems produce a range of services, and these services are frequently closely connected, it is often hard to discuss valuation of a single service in isolation. In addition, valuing multiple ecosystem services typically multiplies the difficulty of evaluation
  - Last to be reviewed are analyses that attempt to encompass all services produced by an ecosystem. Such efforts will typically face large gaps in understanding and information in both ecology and economics
- Chapter 5 also includes an extensive discussion of various implications and lessons learned from the case studies that are reviewed. For some policy questions, enough is known about ecosystem service valuation to help in decision-making. For others, knowledge and information may not yet be sufficient to estimate the value of ecosystem services with enough precision to answer policy-relevant questions

Case Studies and Lessons Learned
Major Recommendations

- Estimates of ecosystem value need to be placed in context; assumptions about conditions in ecosystems outside the target ecosystem and assumptions about human behavior and institutions should be clearly specified
- Concerted efforts should be made to overcome existing institutional barriers that prevent ready and effective collaboration among ecologists and economists regarding the valuation of ecosystem services. Furthermore, existing and future interdisciplinary programs aimed at integrated environmental analysis should be encouraged and supported

Judgment, Uncertainty, and Valuation

- The valuation of aquatic ecosystem services inevitably involves investigator judgments and some amount of uncertainty. Although unavoidable, uncertainty and the need to exercise professional judgment are not debilitating to ecosystem valuation
  - It is also important that the sources of uncertainty be acknowledged, minimized, and accounted for in ways that ensure that a study's results and related decisions regarding ecosystem valuation are not systematically biased and do not convey a false sense of precision
- There are several cases in which investigators must use professional judgment in ecosystem valuation regarding how to frame a valuation study, how to address the methodological judgments that must be made during the study, and how to use peer review to identify and evaluate these judgments
  - However, when such judgments are made it is important to explain why they are needed and to indicate the alternative ways in which judgment could have been exercised
- Just as there are different types of uncertainty in ecosystem valuation, there are also different ways and decision criteria that an analyst can use to allow for (and reduce) uncertainty in the support of environmental decision-making

Judgment, Uncertainty, and Valuation
Major Recommendations

- If the good or service being valued is unique and not easily substitutable with other goods or services, then the decision to use WTP or WTA are likely to result in very different valuation estimates
  - In such cases, the committee cannot reasonably recommend that the analyst report both sets of estimates in a form of sensitivity analysis because this may effectively double the work; rather, the analyst should document carefully the ultimate choice made and clearly state that the answer would probably have been higher or lower had the alternative measure been selected and used
- Ecosystem valuation studies should undergo external review by peers and stakeholders early in their development when there remains a legitimate opportunity for revision of the study's key judgments
- Analysts should establish a range for the major sources of uncertainty in an ecosystem valuation study whenever possible
- Under conditions of uncertainty, irreversibility, and learning, there should be a clear preference for environmental policy measures that are flexible and minimize the commitment of fixed capital or that can be implemented on a small scale on a pilot or trial basis

Ecosystem Valuation: Synthesis And Future Directions

- Chapter 7 seeks to synthesize the current knowledge regarding ecosystem valuation in a way that will be useful to resource managers and policymakers as they incorporate the value of ecosystem services into their decisions, and includes the following:
  - A synthesis of the report's general premises (10 total)
  - A synthesis of the report's major conclusions
  - Guidelines and a checklist for conducting ecosystem services valuation
  - Overarching recommendations for conducting ecosystem valuation
  - Overarching research needs, which imply recommendations regarding future research funding

VALUING ECOSYSTEM SERVICES

TOWARD BETTER ENVIRONMENTAL DECISION-MAKING

Lake Mendota, Wisconsin. Photo courtesy Wisconsin Department of Natural Resources

Until the economic value of ecosystem goods and services is acknowledged in environmental decision-making, they will implicitly be assigned a value of zero in cost-benefit analyses, and policy choices will be biased against conservation. The National Research Council report, *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*, identifies methods for assigning economic value to ecosystem services—even intangible ones—and calls for greater collaboration between ecologists and economists in such efforts.

The millions of miles of rivers, streams, coastline, and acres of estuaries, wetlands, lakes, and reservoirs throughout the United States host a vast array of aquatic ecosystems that provide many benefits to humans. These ecosystems produce not only goods such as lumber and fish, but they also provide a number of important functions or services that play crucial roles in supporting human, animal, and plant populations. These services include nutrient recycling, habitat for plants and animals, flood control, and water supply (see Box 1).

Human activities often compete with ecosystem survival. For example, should a wetland be drained for suburban housing? Although the economic value of the new houses may be known, it is not as easy to quantify the value the lost ecosystem services of the wetland that would affect plant and animal life, alter storm runoff patterns, and interfere with water reclamation, among other impacts. Likewise, the decision to build a dam to meet drinking water and electricity needs could have dramatic consequences on downstream ecosystems.

In order to appropriately assess environmental policy alternatives and the decisions that follow, it is essential to consider not only the value of the human activity, but also to consider the value of the ecosystem service that could be compromised. Despite a growing recognition of the importance of ecosystem services, their value is often overlooked in decision-making, and, to date, that value has not been well quantified.

Valuation Should Measure Trade-Offs

The Catskills/Delaware watershed provides 90 percent of the drinking water for the New York City metropolitan area. Historically, the watershed has produced high quality water with little contamination, but increased housing developments, septic systems, and agriculture caused water quality to deteriorate. By 1996, New York City had two choices: build a water filtration system at an estimated cost of up to $6 billion or protect its major watershed.

When possible in environmental decision-making, policymakers should use economic valuation as a way

Box 1. Examples of Services from Various Aquatic Ecosystems

Wetlands transform inputs (nutrients, energy) into valuable outputs (fish, crustaceans, and mollusks).

Floodplains along rivers and coasts provide flood protection, water reclamation, pollution abatement, underground water recharge, and recreation.

Mountain watersheds provide water supply, recreation (e.g., hiking, camping, and fishing).

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to quantify the trade-offs in a policy choice. In order to protect the Catskills watershed, measures were taken to help limit further development, improve sewage systems, and reduce the impact of agriculture by using less fertilizers and building up riparian zones along river banks at a total projected investment of about $1 to $1.5 billion. New York City water managers chose to protect the watershed.

Link Economic and Ecological Models

In the Hadejia-Jama'are floodplain in Northern Nigeria, economists and hydrologists worked together to estimate both upstream benefits and downstream consequences of several proposed dam and water diversion projects. A 1998 study showed that the benefit of the project was $3 million in irrigation and potable water, but that downstream floodplain losses would result in about $23 million dollars in costs; an estimated net loss of $20 million. A study in 2001 found that a one meter drop in groundwater would result in an estimated $1.2 million loss in dry season agriculture and a $4.8 million loss in domestic water consumption for rural households.

Economists already produce estimates of value for environmental decision-making. However, the strength of their analysis depends in large part on how well the underlying ecology of an ecosystem is understood and measured. Ecologists are challenged because ecosystems are complex, dynamic, variable, interconnected, and nonlinear, and because our understanding of the services they provide and how they are affected by human actions are imperfect and difficult to quantify.

In an analysis, it is important to ensure that the ecosystem is well understood and also that the study is designed so that output from ecological models can be used as input to the economic models so that the two can be linked effectively. The example of the Nigerian floodplain also illustrates the importance of measuring expected *changes* in the ecosystem for a given ecological impact. Other changes that could be measured include stream flow, water temperature, and changes in the plant life and fish of the floodplain.

Consider All Ways Ecosystems are Valued

Clean drinking water, food production, and recreation are all services of a lake ecosystem, but it is not easy to measure each one separately or to resolve conflicting views on which is more or less important to a management decision. Many economists use the **Total Economic Valuation (TEV) Framework** to incorporate the multiple ways that individuals or groups could value an ecosystem—most of which have no market or commercial basis (see Figure 1). Elements of the framework include:

- **Use and Nonuse Values:** Although different TEV frameworks are used to assess value, most

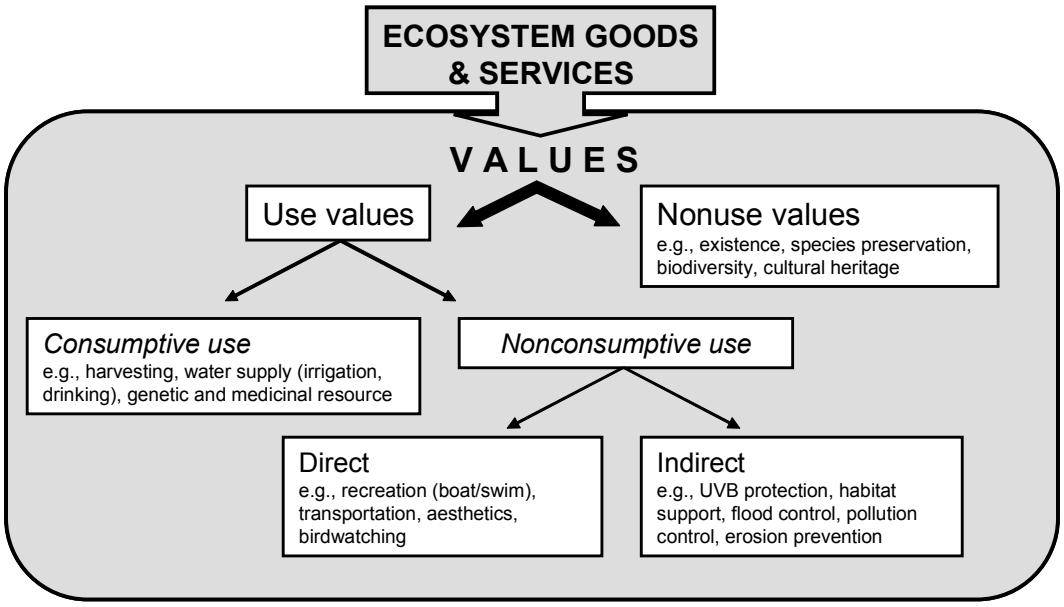

Figure 1. The figure shows the multiple types of values from ecosystem goods and services that are considered within a total economic valuation (TEV) framework.

of them include both "use" and "nonuse" values. For example, an oil spill on a popular beach that prevents people from using it represents lost use value. Alternatively, if the oil spill did not disrupt beach use, but damaged plant and animal life offshore, this would represent a lost nonuse value. Use values can be further divided into consumptive uses (goods, water supply) and nonconsumptive uses (recreation, habitat support, flood control).

- **Willingness to Pay and Willingness to Accept:** If the quality of a freshwater lake were improved to enhance sportfishing, the economic measure of the value of such an improvement to a recreational angler would be measured by his *willingness to pay* for such a change. If however the quality of a lake was worsened from its current level, then the economic measure to a recreational angler would be his *willingness to accept* compensation for the damage, or the minimum amount of money the angler would accept as compensation.

Quantify Ecological Impacts

How can a dollar amount be applied to ecosystem changes? There are several economic methods that can be used to place a value on ecosystem services (see Box 2). These methods base values on various aspects of consumer and producer behaviors, and draw on stated or revealed individual preferences.

In the Great Lakes, policymakers conducted a complex analysis to decide whether and how to control the sea lamprey, an invasive species that preys on the native lake trout, sturgeon, salmon, and other large fish. One study polled 2,000 Michigan anglers to estimate the value to them of a higher catch rate at various fishing sites, taking into consideration distance and travel costs to those sites. The study showed that even a 10% increased catch rate would have a value of about $3.3 million to fisherman. This value was compared against the cost of various methods to control the sea lampreys, for example using a lampricide treatment, so that an appropriate decision could be made.

Specific attention should be paid to pursuing research at the "cutting edge" of the valuation field to support this type of analysis. Because they are time consuming, project-specific valuations have sometimes been replaced by the benefits transfer method, which assesses value based on an existing study of a similar ecosystem. However, benefit transfer methods should be considered second best to careful analysis of the specific ecosystem in question.

Incorporating Judgment and Uncertainty

Perhaps the most important choice in any ecosystem valuation study is how the initial question is framed. In the Catskills/Delaware watershed, policymakers made the critical decision early on that it was not necessary to value all the services of the watershed, but instead to focus only on water quality. Other judgments may be necessary in framing an issue, for example the choice between using the

Box 2. Assigning a Dollar Value: Nonmarket Valuation Methods

Following are some of the most common methods that are used to measure the economic value of ecosystems services.

Household Production Function Methods model consumer behavior based on the assumption that ecosystem services can be substitutes for or complementary to a marketed commodity. Travel-cost models infer the value of an ecosystem according to the travel time and costs needed to visit it. Averting behavior models quantify what people would spend to avoid a negative impact on health, for example installing a filter if water quality is poor. Hedonic methods analyze how characteristics, including environmental quality, alter how much people would pay for something.

Production Function Methods model the behavior of producers and their response to changes in environmental quality that influence production. These methods have been applied to explore the habitat-fishery, water quality-fishery linkages, and erosion control and storm protection.

Stated-Preference Methods are commonly used to measure the value people place on a particular environmental item. Examples include how much people would pay annually to obtain swimmable, fishable, and drinkable freshwater, or to protect

Pooling Revealed- and Stated-Preference Methods uses combined data from different valuation methods to estimate a single model of preferences.

Benefit Transfer Methods estimate the value an ecosystem based on existing studies of a roughly similar ecosystem.

concept of willingness to pay or willingness to accept in an analysis.

Uncertainty can arise at many steps in an analysis. For ecosystem valuation, one of the biggest sources of uncertainty is the lack of probabilistic information about the likely magnitudes of some variables. Other sources of uncertainty arise from models or parameters used. Economic factors can introduce uncertainty as well. For example, how does the degree of visible cleanliness or the degree of development and crowding affect the value of a popular recreational watersite?

Although uncertainty and judgment are inevitable, they are not debilitating to ecosystem valuation and do not undermine the validity of the analysis. It is only necessary to provide a clear explanation of how judgments were made and how uncertainties were accounted for.

Overarching Recommendations

When faced with environmental policy decisions that seek to balance human activity and conservation, the process of valuing ecosystem services can inform the policy debate and lead to better decision-making. The report makes the following recommendations for how policymakers should conduct ecosystem valuations:

- Seek to evaluate trade-offs: where possible, value should be measured in a way that makes analysis of trade-offs possible. If the benefits and costs of an environmental policy are evaluated, then the benefits and costs associated with the changes in an ecosystem service must be evaluated as well.
- Frame the valuation appropriately: Measure changes in ecosystem services, rather than the value of an entire ecosystem.
- Delineate all sources of value from the ecosystem and determine whether they are captured in the valuation.
- Quantify ecological impacts where possible beyond a simple listing and qualitative description of affected ecosystem services.
- Make sure that economic and ecological models are appropriately linked. The output from ecological modeling must be in a form that can be used as an input to economic analysis.
- Seek to value the goods and services most important to a particular policy decision.
- Base economic valuation of ecosystem changes on the total economic value framework. Include both use and nonuse values.
- Consider all relevant impacts and stakeholders in the scope of the valuation.
- Scrutinize any extrapolations made across space (from one ecosystem to another), time (from present to future impacts), and scale (from small to large changes) to avoid extrapolation errors.

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This brief was prepared by the National Research Council based on the committee's report. For more information, contact the Water Sciences and Technology Board at 202-334-3422. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making* is available from the National Academies Press, 500 Fifth Street, NW, Washington, DC 20001; 800-624-6242 or 202-334-3313 (in the Washington area); www.nap.edu.

Summary of the Q&A Discussion Following Session I

Bob Leeworthy (NOAA)
Classifying what he had to say as more of a comment than a question, Dr. Leeworthy stated that "in leading many exercises in NOAA in actual management policy applications," he and his colleagues have found that in their dealings with communities, if they don't address "market economic impacts on local sales, income, and employment," they are "shown the door" and are "considered to be irrelevant." He said that he thinks economists need to be careful not to focus just on the net economic values "that we as economists all agree to, but which everyone else would think are irrelevant."

Mark Gibson (National Academy of Sciences)
Mr. Gibson responded that the committee at first was trying to get . . . the economists, and ecologists and the environmental philosopher "on the same sheet of music." Further, he explained that what was presented was "a very short, quick snapshot of the work" and he hoped that a closer inspection of the report would yield more information relevant to the work being done by Dr. Leeworthy and his colleagues at NOAA.

Ann Watkins (U.S. EPA, Office of Air and Radiation)
Addressing her question specifically to Angela Nugent but opening it to other comments, as well, Ms. Watkins said, "I noticed that you mentioned GPRA (the Government Performance and Results Act) as one of the things that you have considered as you looked at the questions that we have to answer, and you also looked at PART" (the Program Assessment Rating Tool), both of which are components of OMB's (Office of Management and Budget) analysis of our different programs. She said that she knew of "several programs [that] have been zeroed out because they can't provide a measure of value that is sufficient for OMB's standards under this PART analysis."

Angela Nugent (U.S. EPA, Science Advisory Board Staff Office)
Dr. Nugent responded that "the GPRA piece is yet to be done by the committee, but it's part of the grand plan." She went on to explain that "as we design our survey of what the Agency is struggling with, I think a necessary part of that is dealing with this program assessment review tool of OMB and seeing how it has been applied to programs whose primary thrust is eco-protection and how the Agency can actually strengthen its science base to make that case." She went on to assert that certain groups within EPA have already begun developmental programs to "strengthen the science" or identify how it can be strengthened. Stating that "all these things that we are now treating as separate threads obviously need to be woven together," Dr. Nugent identified the "ultimate revision of the steering committee" as a "move to a situation where all of these kinds of analyses, regional, national, park level . . . would support each other."

Ed Bender (U.S. EPA, Office of the Administrator)
Dr. Bender opened by stating, "It's very important to value things, because we don't protect them unless we value them." He continued, "However, in ecological risk assessment, one of the fundamental gaps is that *most* of the assessment endpoints deal with individual species—not really with what ecology is about." Dr. Bender wondered if any of the panelists "had noticed that kind of problem and had any thoughts about how economists might be able to help us look at the more complex and higher order interactions that I know you're *trying* to look at as you look at ecosystem goods and services."

Mark Gibson
Mr. Gibson said he would love to have a committee member help address that comment, and began by saying, "There are key studies, I believe in Chapter 4, that talked about invasive species and trying to evaluate . . ."

Ed Bender
(interrupting) "They're an organism. I'm talking about the interaction of organisms with each other as well as with their environment, or habitat loss, or some of the other things that we say are so important, yet we don't really have much information—those are not really addressed in ecological risk assessments."

Geoffrey Heal (Columbia University)
Identifying himself as the Committee Chair, Dr. Heal stated, "I'm not certain that we really address exactly the issue you're dealing with, but what we've done in the report is to look at the valuation of ecosystem services—those services that come from the operation of the ecosystem as a whole, and it relates to the services provided by the ecosystem to the existing structure, for instance the physical and chemical . . . and certain regulatory functions. To the extent that relationships between individual species or the existence of particular species affects the services or improves the services that come out of an ecosystem, then I guess the result you could lay out can, in some instances, attach value to the existence or the interaction between the individual species. It's not the task of the report, really, but whether we construe this, it will place a value on a particular species, other than maybe its charismatic value, because that's a non-use value. But to the extent that species don't obviously have a straight existence value because of their charismatic characteristics, I don't think we really address the issue how you would value individual species. I guess the perspective we would take is that species are part of what makes an ecosystem function, and if you would pull a species out of an ecosystem—particularly pull a keystone species out of an ecosystem, for example—the services provided by the system can collapse. So, there's the *implicit* value in the species because of that.

Nicole Owens (U.S. EPA, NCEE)
Dr. Owens offered "one quick response to that: One of the things we talk about in the strategic plan is how they can use that kind of information to communicate functioning of ecosystems to the public, and also use that to address uncertainty and how you might describe how uncertain some of our estimates of the changes in ecosystems might be to

the public. She added, "That should come in handy whether you're developing either surveys or focus groups—to use that information you may have on one species to try and convey to the public something about the functioning of the whole ecosystem."

Al McGartland (U.S. EPA, NCEE)
"I have some advice for Dr. Leeworthy: At EPA sometimes we can shame the decision-makers into listening about benefits—after all, decision-makers should be interested in improving the welfare of society. I often refer back to the GDP accounts—a lot of the welfare improvements that come from environmental improvements don't get captured in the GDP accounts, and that's actually, I think, a good hook into benefit analysis."

"My question really is that I struggle with benefits and ecosystem stuff—it seems this whole spatial dimension is a big problem: ecologists like to do these very localized things, and of course national regulations require national benefits. I ask the panel and Geoff and maybe others later to address the question: Is that a show-stopper or is there hope on the horizon for dealing with that?"

Mark Gibson
Mr. Gibson's general response was that the issue is, in fact, a concern of ecologists and it is addressed in his Chapter 3, along with "focused conclusions and recommendations in that regard." He concluded by saying he would not characterize it as a "show-stopper" but that it was a difficult issue for the committee to tackle and they went as far as they could in developing conclusions and recommendations to that effect.

Liz Strange (Stratus Consulting, Inc.)
In response to Dr. Bender's question, Dr. Strange stated that she and her colleagues did some work in the last few years where they looked "specifically at the eco-risk assessment framework at EPA and tried to think in terms of ecosystem services, the goods and services provided by ecosystems, as potential assessment endpoints." She went on to say the she thinks "that's one of the ways to get at what you're talking about because, of course, those goods and services depend upon ecological structures and functions—in some cases depend on individual species or communities." Dr. Strange said she believes that on the Global Change Research Program website there is a copy of that framework, which "essentially was integrating the eco-risk framework of EPA with the natural resource damage assessment approach that focuses on ecological . . . services."

As an example of "another attempt to try and get at those things and integrate those things," Dr. Strange also mentioned that she previously worked with one of the members of Mr. Gibson's committee, Al Kovitch, on "an EPA/NSF-funded project looking at ecological integrity and what are some of the endpoints that you can use to present to the public information about what we mean by *ecological health* or *ecosystem services.*" She closed by adding that "there was an evaluation study associated with that research."

Angela Nugent
Dr. Nugent referred back to the question about spatial scales and said that the issue came up when they did an example exercise on the CAFO (Concentrated Animal Feeding Operations) analysis. She said some folks on the committee were strong proponents of "having case studies be part of the benefits assessment supporting the rule, either as stand-alone case studies or something that could be used to test and validate the national model . . ." Dr. Nugent continued by saying that there is a general sense, especially at the region level, that "there's a tremendous opportunity there to build on this local experience, and maybe there are some leads on the empirical side that will help us answer the question you asked." She said she thinks people on the SAB Committee are going to look more in depth at this question of spatial scale—and also temporal scale, the duration of a study and what assumptions are made about change over time.

END OF SESSION I Q&A